1.3 Motors and Generators

When your friends aren't nearby, what's the best way to communicate with them? You could give them a phone call; send them a text message with your cellphone; or, if you were close to a computer, you could use the latest instant-messaging software. Many communication technologies require the use of an integrated headset that combines a microphone with headphones.

Multiplayer computer games also use headphone and microphone technology. Websites that provide technical support to gamers include recommendations for accessories as well as suggestions for getting started if it's your first time using voice communication while gaming. One such website suggests that if you don't have a microphone for your computer, you can plug a set of headphones into the computer's microphone input and then speak into the headphones as if they were a microphone. The website goes on to explain that although headphones may be a little inconvenient to use and the sound quality may not be as good as a microphone, they can provide acceptable results until you get a proper microphone.

Figure C1.27: Many multiplayer computer games allow participants to communicate with each other using headphones and a microphone.

Figure C1.28: Headphones can be used as a microphone.

What processes enable a set of headphones to be used as a microphone? Does this work equally well with all headphones, or are some better suited to this conversion than others? In this lesson you will have an opportunity to complete investigations that will enable you to answer these questions. The essential components involve magnets and coils of wire carrying electric currents—things you investigated in the previous lesson. However, now you must also consider the conversions that occur between **electrical energy** and **mechanical energy**.

Recall from previous science courses that mechanical energy is a quantity used to describe objects, like tennis balls, that can be directly observed. A tennis ball that is hit high into the air has both kinetic energy, because it is moving, and gravitational potential energy, due to its height.

electrical energy: the energy made available by the movement of charge

mechanical energy: the energy possessed by an observable object due to motion or its position; the sum of the kinetic energy and potential energy of an object

Electrical energy is more challenging to study because it is due to the movement of charges in fields. Since neither charges nor fields are directly observable, electrical energy is easiest to investigate indirectly through its conversion to other forms of energy, such as sound, light, thermal energy, or mechanical energy. The electric motor is a great place to begin looking at this energy conversion because the mechanical energy can be measured and because there are so many interesting applications.

Practice

22. Sound is considered a mechanical wave because matter is given both kinetic and potential energy as the sound wave passes through. Often these vibrations occur too rapidly to see, but you can detect the vibrations with your sense of touch. Provide an example of a sound vibration in which you may be unable to see the matter vibrating but you can feel the vibrations with your fingertips.

23. Headphones and microphones both involve conversions between electrical energy and mechanical energy. A key difference between the two devices is the order of the energy conversion.

- **a.** Describe the order of the energy conversion for a microphone and for a headphone.
- **b.** Your sense of hearing involves an energy conversion as the vibrations of matter are converted into a signal that is sent to your brain. Describe the order of the energy conversion in your sense of hearing.

Electric Motors

Think of all the tasks you have to do in a typical day. How many of them involve electric motors? Preparing food, doing laundry, using tools, and even drying your hair can all be done using the spinning motion of a motor. If you have a chance to look inside some of these devices, you will see the same basic parts arranged in slightly different ways, depending upon the task.

The student-built motor in Figure C1.29 includes all the key components. The part of the motor that spins is called the **armature**. Electric current flows into the armature through the **commutator** to the turns of wire that form the coil. When the coil rotates, the **shaft** also rotates since these parts are connected. As the shaft rotates, it does the useful work the motor was designed to accomplish. In a hair dryer, the rotating shaft turns the blades of a fan to generate a stream of fast-moving air.

The lower section of Figure C1.29 includes all parts of the motor that do not move. The voltage source provides electrical energy to charges so that an electric current can be formed. The electric current enters the armature through each **brush** that gently makes contact with the commutator. Before the moving charges pass back through the commutator and return to the voltage source, they must circulate through the loops of wire in the coils of the armature. But how exactly is electrical energy converted into mechanical energy in this design? You will have an opportunity to answer this question in the next investigation.

- **armature:** the section of a motor or generator that rotates, consisting of a coil of wire, a rotating shaft, and a commutator
- **commutator:** a part of a motor or generator found on the armature that provides electrical contact, allowing current to flow to the rotating coil
- **shaft:** a part of a motor or generator that supports the coil of the armature, providing an axis for the rotation of the armature
- **brush:** a stationary part of a motor or generator that makes electrical contact with the rotating commutator

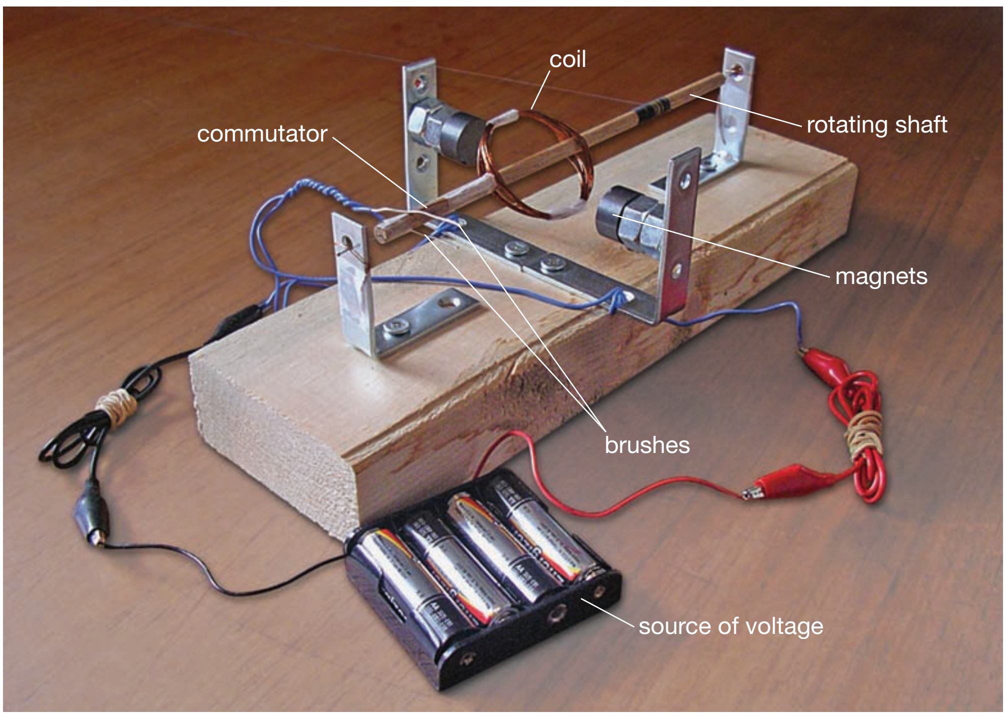


Figure C1.29: A student-built motor

Investigation

Building an Electric Motor

Purpose

You will build a working electric motor and test its ability to function as a spooling machine or as a miniature crane.

Science Skills

✓ Performing and Recording
✓ Analyzing and Interpreting
✓ Communication and Teamwork

Materials

- 4 AA cells in a plastic battery pack with leads
- 3, 5.0-cm bolts
- 2 test leads
- 2, 0.50-m pieces of solid, insulated 20-gauge connecting wire
- block of wood (3.5 cm by 9 cm by 30 cm)
- 2 metal angle brackets with predrilled holes (each side about 5.0 cm long)
- 2 metal angle brackets with predrilled holes (each side about 6.3 cm long)
- 4 wood screws (about 5.0 cm long)
- 4 hex nuts ($\frac{7}{16}$-inch thread size)
- 6 ceramic disc magnets (about 1.8 cm in diameter and 1 cm thick)
- piece of wood dowelling (about 6 mm in diameter and exactly 20.0 cm long)
- 5 m of 26-gauge enamelled magnet wire
- cylindrical glassware with a diameter of 3–4 cm
- scissors
- "Building the Armature" handout
- 2 straight pins (2.5 cm long)
- 4 m of black thread
- 10 small paper clips
- ring stand
- large "bulldog" paper clamp
- transparent adhesive tape
- sharp knife
- wire cutters
- wire strippers
- pliers
- screwdriver
- digital multimeter or a voltmeter
- fine sandpaper
- "Building the Stationary Parts" handout

CAUTION!

Be sure to disconnect the cells from the motor when it is not running. This prevents the cells from draining unnecessarily. Also, the small coil of wire can become warm to the touch if an electric current runs through it when the armature is not turning.

Part A: Building the Armature

Obtain the handout "Building the Armature" from the Science 30 Textbook CD. Follow the steps outlined on this handout to assemble the armature of the motor.

Part B: Building the Stationary Parts

Obtain the handout "Building the Stationary Parts" from the Science 30 Textbook CD. Follow the steps outlined on this handout to assemble the stationary parts of the motor.

Part C: Getting the Motor to Run

step 1: Use the digital multimeter to ensure your battery of AA cells is producing 6.0 V of voltage.

step 2: Turn the armature so that the coil is vertical and the brushes do not make contact with the commutator. Use the test leads to connect the voltage source to the end leads of the connecting wire. Gently move the armature with your finger until contact is made between the brushes and the coil. Your motor should start to spin.

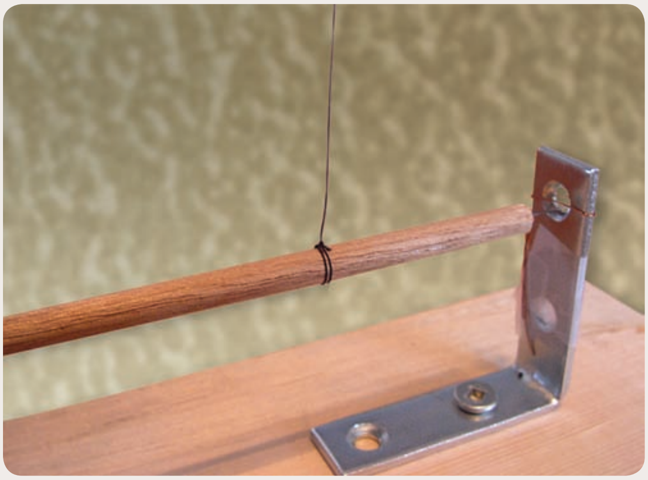
If it does not spin, disconnect the voltage source and begin to troubleshoot.

- A poor connection between the brushes and the commutator is the most common problem. When the coil is in a horizontal position, the exposed copper wires of the commutator should be contacting the brushes.
- If there is too much pressure between the wires that form the brushes, the armature will not spin well. If there is too little pressure, there will be poor contact and current will not flow through the coil.

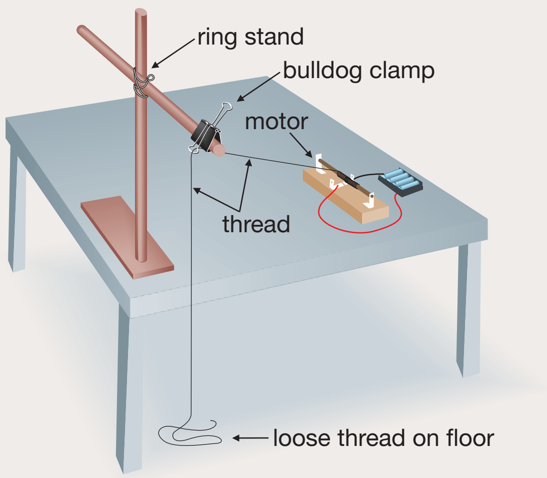
step 3: Adjust the components of the motor so that the armature turns as rapidly and as smoothly as possible.

Reminder: While troubleshooting, only connect the motor to the voltage source for a few seconds at a time. If an electric current flows through the coil for a long time, the coil will get warm to the touch and the cells will become drained.

step 4: Attach the black thread to the end of the shaft on the end opposite from the coil. A ring stand set up beside the motor can be used to create a "looping path" for the thread that goes from the floor, up to a bulldog clamp on the ring stand, and then down to the shaft of the motor. Ensure that the thread can be easily pulled along this path with very little resistance.

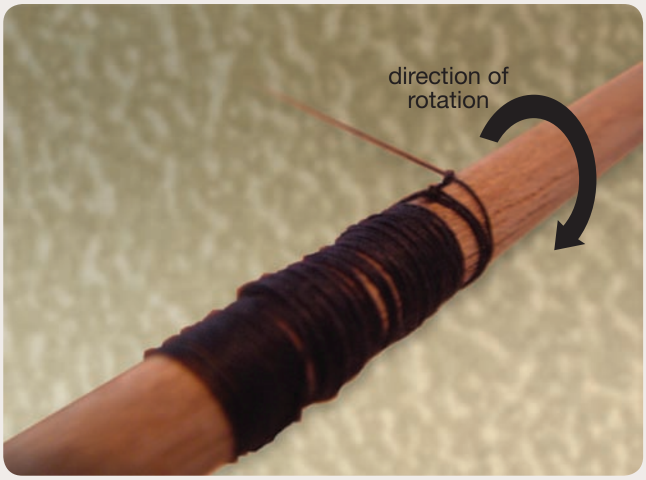


step 5: Use your motor to spool the thread onto the rotating shaft of the armature. Once the end of the thread has been reached, disconnect the voltage source and gently pull the thread back through its path until some of the thread lies loose on the floor again.



step 6: Note that the motor will naturally tend to wrap the thread in a particular direction as it spins. Did you know that you can reverse the direction of the armature's rotation if you wish to wrap the thread in the opposite direction?

Devise two different adjustments you can make to the components of the motor that will cause the thread to reverse the armature's direction of rotation. Test each of these adjustments by seeing which way the thread spools each time.



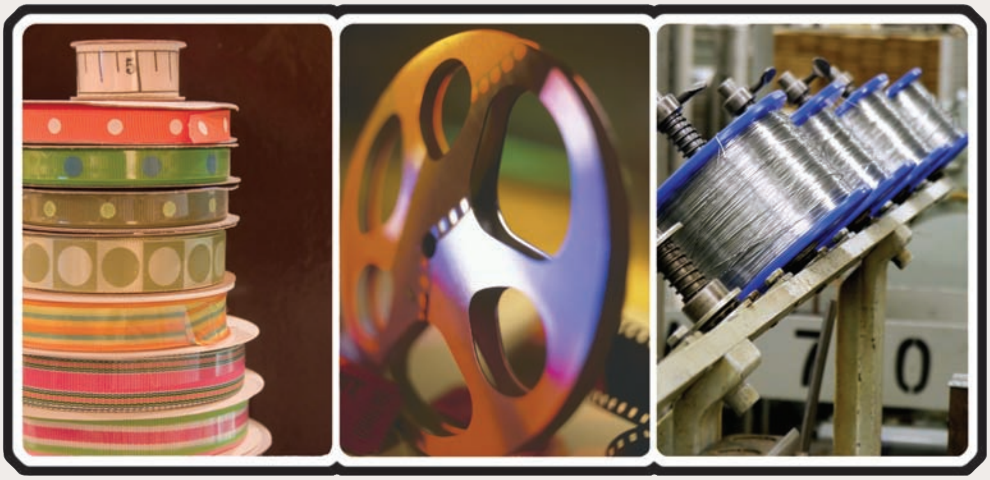
Analysis

1. Describe the adjustments you made to the components of the motor to cause the thread to spool in a different direction.
2. Produce a number of labelled diagrams to explain why each of the adjustments you described in question 1 was able to cause the motor to reverse its direction of rotation.

Part D: Improving Energy Efficiency

Background Information

What do ribbon, movie film, and industrial wire all have in common? Each of these products is put on spools by a motor. In each case, it makes good business sense to operate the spooling motor using as little electrical energy as possible. In this part of the investigation you will try to minimize the voltage required by the motor to spool the thread.



The battery of four AA cells can be adapted so it can run on fewer cells. Every time you replace a cell with a 5.0-cm screw, you decrease the voltage output by 1.5 V. In this part of the investigation you will spool the thread with your motor using as little electrical energy as possible.

step 1: Replace one of the AA cells in the battery pack with a screw, as shown in Figure C1.30. Use the digital multimeter to confirm that the voltage is now 1.5 V less than it was before.

step 2: Gently pull the thread back through its path until there is again some loose thread on the floor.

step 3: Using the proper procedure, set up your motor and run it. Is the motor still able to spool the thread? Make any necessary adjustments so that the motor is able to spool the thread with the reduced voltage.

step 4: If the motor was able to spool the thread in step 3, continue testing to see whether a further reduction in voltage is possible. Repeat steps 1 through 3.

step 5: Repeat step 4.

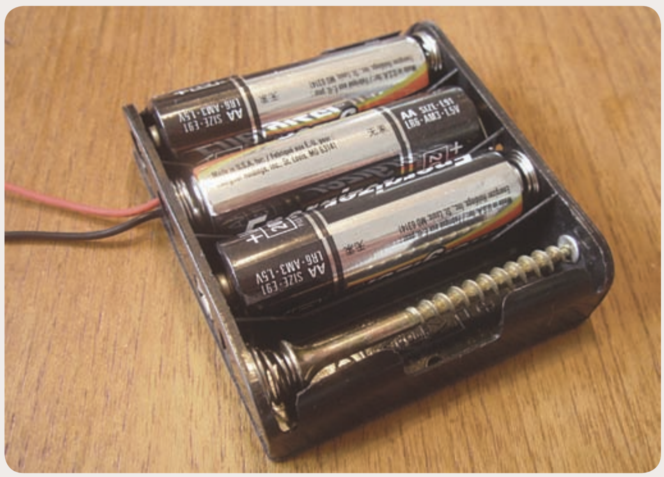


Figure C1.30: A screw replaces one of the AA cells in the battery pack.

Analysis

3. Describe the adjustments you made to the motor so it could perform the task of spooling the thread with less voltage.
4. Each of the adjustments you described in question 3 helped your motor to run more efficiently by reducing the production of unwanted forms of energy. Identify the type(s) of unwanted energy that were reduced due to each of your adjustments.
5. List the benefits a business might experience by running more-efficient electric motors.

Part E: Improving the Motor's Ability to Do Work

Dockside cranes lift heavy cargo to and from ships. As the massive load is raised in the air, work is done and the cargo gains gravitational potential energy. If this is the output energy for the crane, what is the input energy? Usually, cranes such as these use electrical energy to drive their powerful motors.

In this part of the investigation you will make more adjustments to your motor so that it will be able to lift a load of paper clips while it is reeling in the thread.

Procedure

step 1: Use the digital multimeter to test that your battery of four AA cells is producing 6.0 V.

step 2: Gently pull the thread back through its path until there is some loose thread on the floor again. Make a small loop in the end of the thread and attach one paper clip.

step 3: Using the proper procedure, set up your motor and run it. Is the motor still able to spool the thread and lift the paper clip from the floor to the top of the ring stand? Make any necessary adjustments so that the motor is able to act as a crane and lift the paper clip. As soon as the paper clip reaches the top of the ring stand, disconnect the battery pack.

> **Remember:** You can replace the hex nuts acting as spacers with additional magnets. Just remember to ensure that the magnets on opposite sides are oriented so that they will attract one another.

step 4: Repeat steps 2 and 3 by adding additional paper clips until the motor is no longer able to successfully lift the paper clips from the floor to the top of the ring stand. Record the maximum number of paper clips your motor was able to lift.

step 5: Once you have determined the maximum number of paper clips your motor is able to lift, observe what happens if you disconnect the battery pack when the load of paper clips is at the top of its path. If you have been successful at reducing the frictional losses within your motor, the paper clips should be able to unwind the thread and turn the armature as they fall to the floor. If your motor is unable to do this, add a few more paper clips to the end of a raised load so that the dropping load is able to unwind the thread and turn the armature.

Analysis

6. Describe the adjustments you made so the motor could lift the maximum number of paper clips.
7. Using the same basic design, think of ways in which the motor could be modified to be more powerful. Describe some of the possible modifications that would likely enable the motor to lift even more paper clips.
8. Describe the energy conversion that occurs when the load of paper clips drops to the floor.

Part F: Converting the Motor into a Generator

Background Information

In the introduction to this investigation, it was explained that a motor is a device that converts electrical energy into mechanical energy. Do you think it is possible to reverse this process and convert mechanical energy into electrical energy?

In Part E of this investigation, you were able to get the falling paper clips to unwind the thread and turn the armature. In this part of the investigation you will look for evidence that electrical energy is produced as the coil is forced to turn through the field of the permanent magnets.

Procedure

step 1: Using the proper procedure, use your motor to lift the maximum number of paper clips to the top of the ring stand.

step 2: Once the load has reached the top, disconnect the battery pack at the same instant that a partner holds the paper clips so they do not fall.

step 3: Replace the battery pack with a digital multimeter set up as a voltmeter, as shown in Figure C1.31.

step 4: Set the meter to the most sensitive scale so that it is capable of reading a few millivolts.

step 5: While carefully observing the number of millivolts on the display, ask your partner to let the paper clips fall to the floor. Note the maximum number of millivolts displayed as the armature is forced to turn.

step 6: Determine the effect on the value for the maximum output voltage if you reduce the number of magnets.

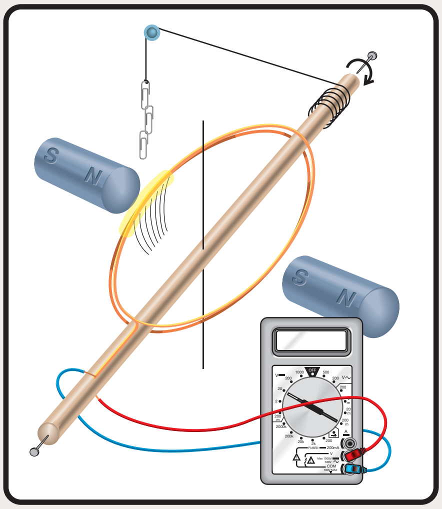


Figure C1.31

Analysis

9. Describe the energy conversions that occur in this part of the investigation.

10. The voltage required to raise the maximum number of paper clips was 6.0 V. The voltage generated by the same number of paper clips falling was much less. How do you account for the difference between these two values?

The Role of Electric Current

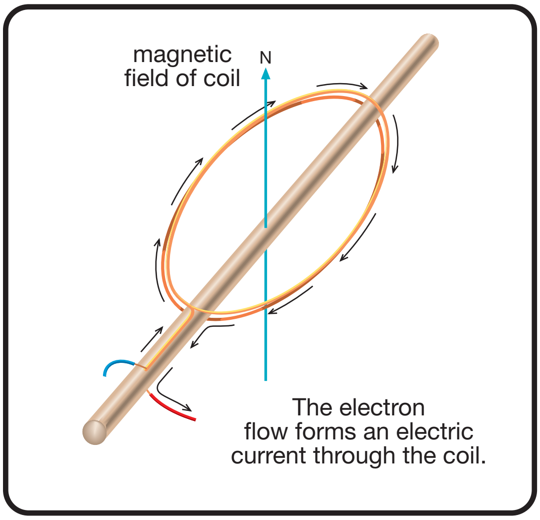


Figure C1.32

The motor you studied in the "Building an Electric Motor" investigation was able to operate because of the interactions between the armature and the stationary magnets. At the heart of this interaction is the electric current flowing through the coil. Figure C1.32 represents electric current with tiny arrows to show the direction in which electrons flow around the loop of the coil. You were able to vary the amount of electric current that flowed through the loop by changing the number of AA cells in the battery pack. As the number of cells increased, the armature was able to spin faster, suggesting that the electric current through the loop had increased. A better way to describe electric current is to use an equation.

electric current (A) → $I = \frac{q}{t}$ ← electric charge (C) / ← time interval (s)

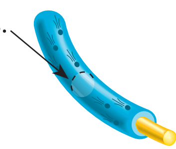
$$\text{Units: } 1 \text{ ampere} = \frac{1 \text{ coulomb}}{1 \text{ second}}$$

Electric current is measured in amperes, which is often shortened to "amps" in everyday speech. When one ampere of electric current is flowing, one coulomb of charge is passing a point in a wire every second. If more charges are able to pass a point in a wire in a given time interval, the value of the electric current is larger, as shown in the following diagrams and calculations.

4.0 C pass this point in 2.0 s.

$$\begin{aligned} I &= \frac{q}{t} \\ &= \frac{4.0 \text{ C}}{2.0 \text{ s}} \\ &= 2.0 \text{ A} \end{aligned}$$

8.0 C pass this point in 2.0 s.



$$\begin{aligned} I &= \frac{q}{t} \\ &= \frac{8.0 \text{ C}}{2.0 \text{ s}} \\ &= 4.0 \text{ A} \end{aligned}$$

Example Problem 1.8

A refrigerator is an appliance designed to transfer heat from the food inside the refrigerator to the environment outside the refrigerator. This movement of heat is accomplished with a fluid called a refrigerant. An electric motor is used to compress the refrigerant from a gaseous state to a liquid state as it moves through a set of heat-exchange pipes. The humming sound you hear when your refrigerator is running is the sound of this motor working to compress the refrigerant. The electric current required to run the refrigerator motor depends upon the size and efficiency of the refrigerator.

Refrigerators are needed because the activity of bacteria is slowed dramatically at lower temperatures. For example, the bacteria naturally present in milk will cause a glass of milk to spoil in three or four hours if the milk is left out on the kitchen table at room temperature. This same milk can be stored for over a week in the low temperatures of a refrigerator.

a. One model of refrigerator requires about 3.8×10^3 C of moving charge to flow through the coils of the compressor motor over a time interval of 15 min. Calculate the electric current required by this motor.

b. Sometimes a food item is placed in a refrigerator in a way that prevents the door from closing properly. Explain how people who eat the food from this refrigerator could develop food poisoning if this situation were to go unnoticed for several days.

Solution

a. $q = 3.8 \times 10^3\ \text{C}$

$$t = 15\ \cancel{\text{min}} \times \frac{60\ \text{s}}{1\ \cancel{\text{min}}} = 9.0 \times 10^2\ \text{s}$$

$I = ?$

$$I = \frac{q}{t} = \frac{3.8 \times 10^3\ \text{C}}{9.0 \times 10^2\ \text{s}} = 4.2\ \text{C/s} = 4.2\ \text{A}$$

The electric current required by this motor is 4.2 A.

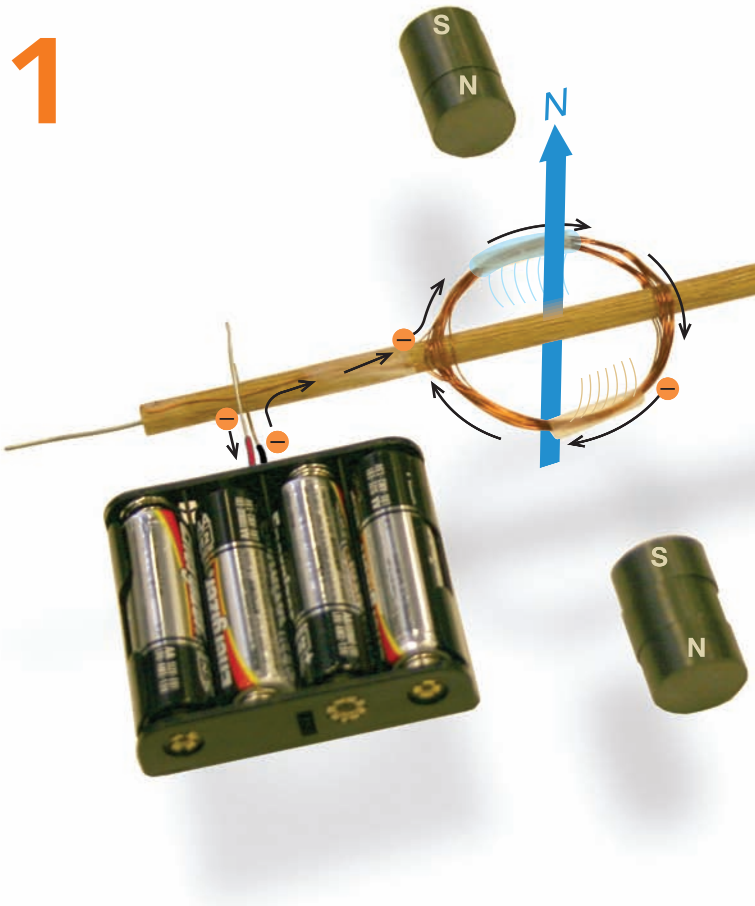
b. If the refrigerator door does not close properly, the space inside the fridge becomes warmer as cool air from inside is exchanged with warm air from the room. As the temperature increases, the number of bacterial cells present on the food increases. When this food is eaten, the number of bacteria that enter the body is much larger than usual. This overwhelms the body's ability to kill the bacteria, causing food poisoning.

Practice

24. The compressor motor of a large refrigerator requires about 1.12×10^4 C of charge to pass through a segment of wire on one of its coils while it runs for 30 min. Determine the electric current that passes through the wire segment as the motor is running.

25. Countries in warm climates often struggle with issues of food storage. Developing countries lack the infrastructure to provide adequate food-storage facilities. Explain how an adequate supply of electrical energy would be advantageous to centralized food-storage facilities in a developing country, especially in a warm climate.

1



Understanding How Motors Work

In this position, the electron flow from the battery is able to pass from the brush to the commutator and momentarily pass through the coil of wire on the armature. Although this connection lasts only a tiny fraction of a second, a large current flows and a large magnetic field is generated around the coil. If the electrons flow in the direction indicated, the top of the coil becomes the north pole.

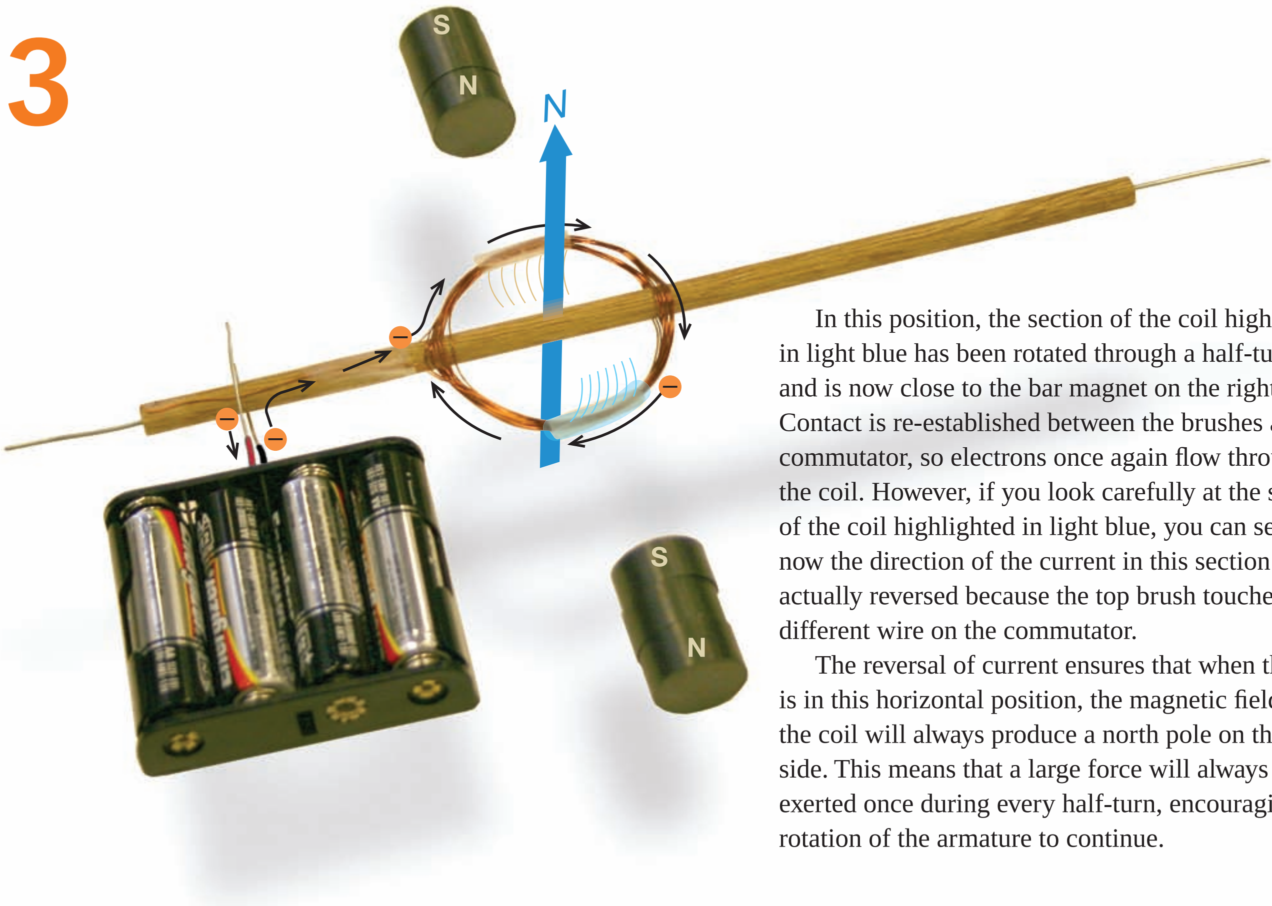
The north pole of the coil is repelled by the north pole of the bar magnet on the left and is attracted to the south pole of the bar magnet on the right. The result of this attraction is rotation. As the armature turns, the section of the coil that is highlighted in light blue is raised by the turning armature.

2

Even though there is no contact between the brush and the commutator, the force provided in the previous step causes the rotation to continue. This is a consequence of Newton's first law of motion, which states that in the absence of a net force, an object in motion will tend to remain in motion.

The forces opposing the rotation of the armature, mainly friction, have not been completely eliminated. Nevertheless, if the force provided in the previous step is great enough, and if the opposing forces are small enough, the rotation of the armature will be enough to rotate the highlighted section of the coil through a half-turn.

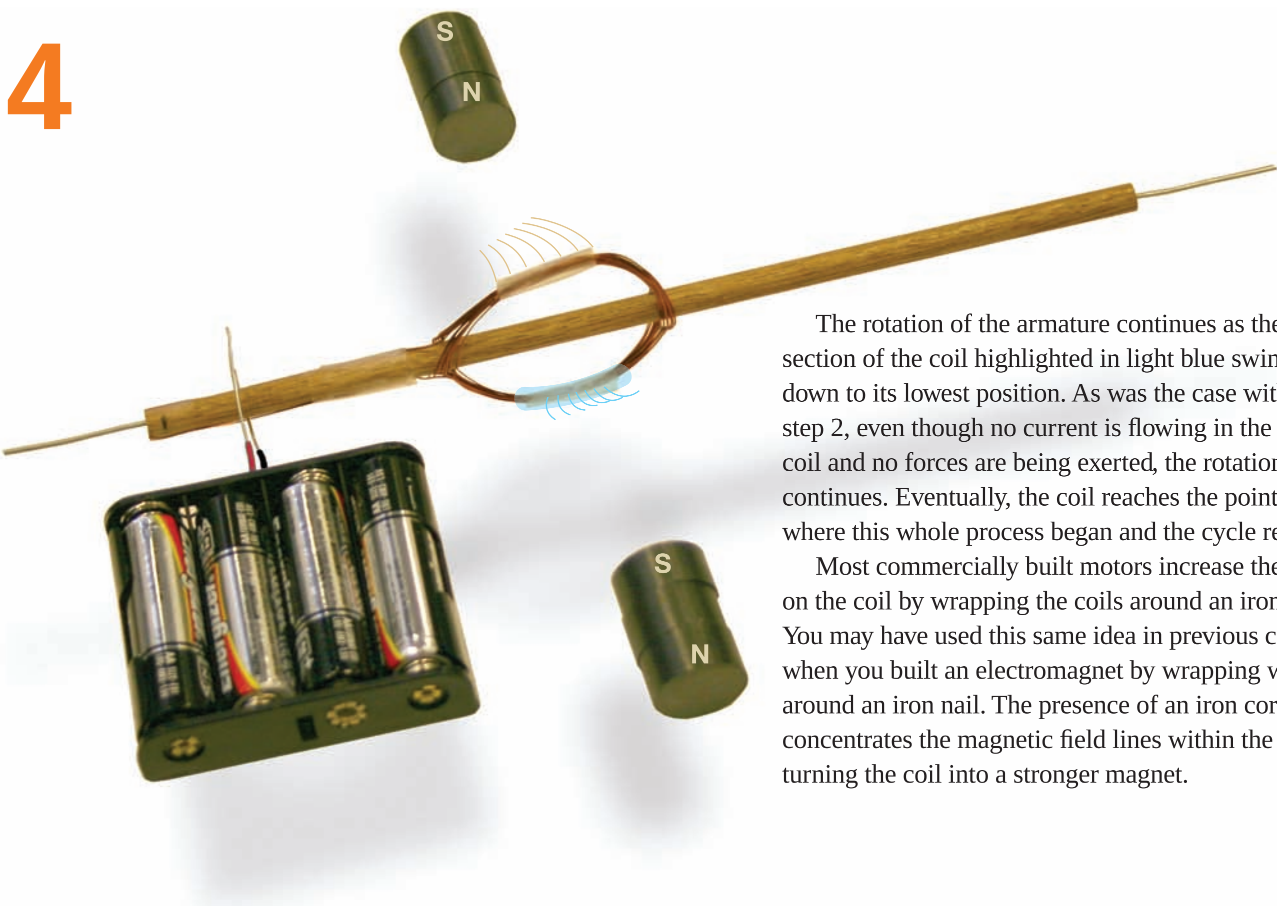
3



In this position, the section of the coil highlighted in light blue has been rotated through a half-turn and is now close to the bar magnet on the right side. Contact is re-established between the brushes and the commutator, so electrons once again flow through the coil. However, if you look carefully at the section of the coil highlighted in light blue, you can see that now the direction of the current in this section has actually reversed because the top brush touches a different wire on the commutator.

The reversal of current ensures that when the coil is in this horizontal position, the magnetic field of the coil will always produce a north pole on the top side. This means that a large force will always be exerted once during every half-turn, encouraging the rotation of the armature to continue.

4



The rotation of the armature continues as the section of the coil highlighted in light blue swings down to its lowest position. As was the case with step 2, even though no current is flowing in the coil and no forces are being exerted, the rotation continues. Eventually, the coil reaches the point where this whole process began and the cycle repeats.

Most commercially built motors increase the force on the coil by wrapping the coils around an iron core. You may have used this same idea in previous courses when you built an electromagnet by wrapping wire around an iron nail. The presence of an iron core concentrates the magnetic field lines within the coil, turning the coil into a stronger magnet.

Practice

26. Obtain the handout "Motor Analysis" from the Science 30 Textbook CD. Describe the direction of rotation for each motor on this handout.

Obtain the handout "Motor Dissection" from the Science 30 Textbook CD. Use the information on this handout to answer questions 27 to 30.

27. Describe the energy transformations that occur within this device.

28. In step 4, the inside of the casing and the inside surface of the magnets are shown. Describe the magnetic poles on the inside surface of each magnet.

29. In step 5, coils are shown mounted on an axle.

- **a.** Identify the name of this whole piece.
- **b.** Identify the name of the three separated contacts at one end of the axle.
- **c.** Suggest the function of the iron core for each coil.
- **d.** The student-built motor studied earlier had only one coil. Suggest the advantages of using three coils.

30. In step 6, a small plastic end cap supports thin metal contacts that connect the motor to the battery pack that runs the motor.

- **a.** Identify the proper name of these metal contacts.
- **b.** Suggest a reason why these contacts have been made from thin material that is light and spring-like.

From Motors to Generators

In the last part of the "Building an Electric Motor" investigation, the motor was converted into an electric generator. As the load of paper clips dropped, the unwinding thread caused the armature to rotate through the magnetic field of the permanent magnets.

The motor and generator both had the greatest forces exerted on the armature when the wires in the coil were moving at right angles to the magnetic field. Unfortunately, the loop is only in this optimum position for a very short time. The problem is compounded by the fact this is the only time when electric current is able to flow from the coil to the multimeter, due to the very brief connection between the brushes and the commutator. The graph in Figure C1.33 shows the output from this generator. Note the occasional spikes in voltage.

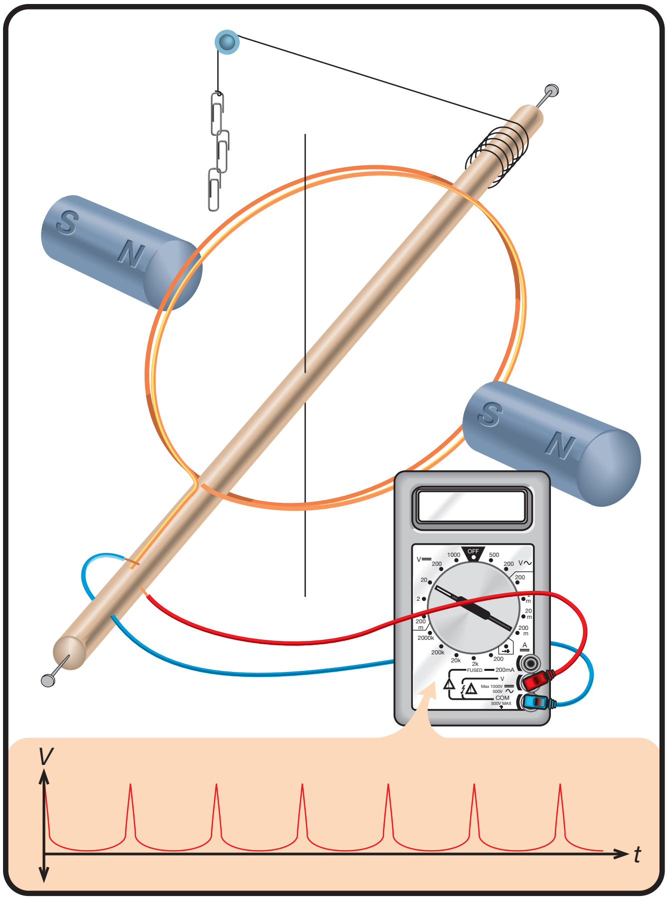


Figure C1.33

This graph explains why the value displayed on the multimeter was so low in the last part of the investigation. The meter displayed long intervals of zero output from the generator punctuated with momentary spikes every half-turn. Although this design was a convenient conversion from the motor, it is clearly not effective at producing useful electrical energy. How could the design be improved?

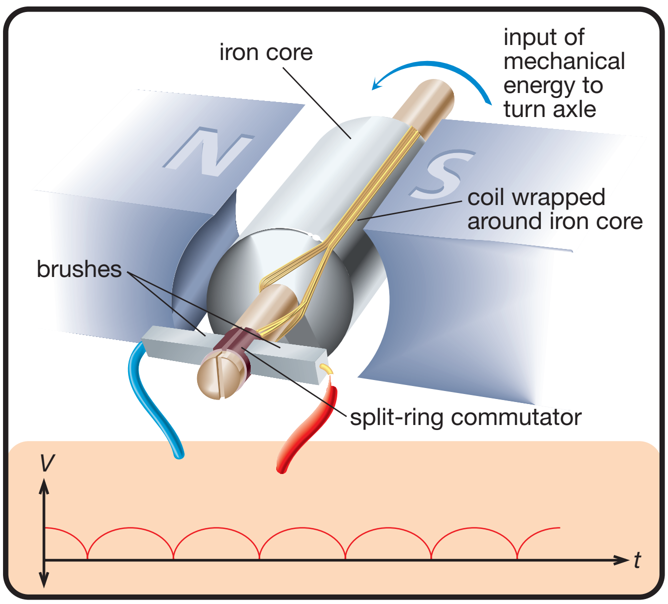


Figure C1.34

Wrapping the coils around an iron core helps to concentrate the effects of the magnetic field lines. Another useful improvement would be to change the commutators from small prongs of wire to a split-ring design that increases the contact time with the brushes. This change allows the electrical energy to be generated for a longer period of time. Note that this same thinking can be applied to the wrap-around shape of the magnets. This ensures that the armature coils are closer to the magnet, where the magnetic field is more intense. The output from this generator shows the effects of these improvements, as shown in Figure C1.34.

Further improvement is possible by positioning more coils at different orientations around the armature, with each one attached to its own commutator. This design means that during any part of a rotation, one of the coils is always in a position to deliver its maximum output. Although the voltage output of this generator design is not completely free of ripples, it is now a useful source of electrical energy. This kind of output from a generator is called **direct current**, or **DC** for short. The name reflects the fact that the value of the electric current generated is constant and that the current flows in only one direction. The ultimate in ripple-free DC sources is a fresh battery because there are no moving parts to create ripples.

direct current (DC): a flow of charges that does not increase or decrease and flows in a single direction

alternating current (AC): a flow of charges that reverses directions at regular intervals

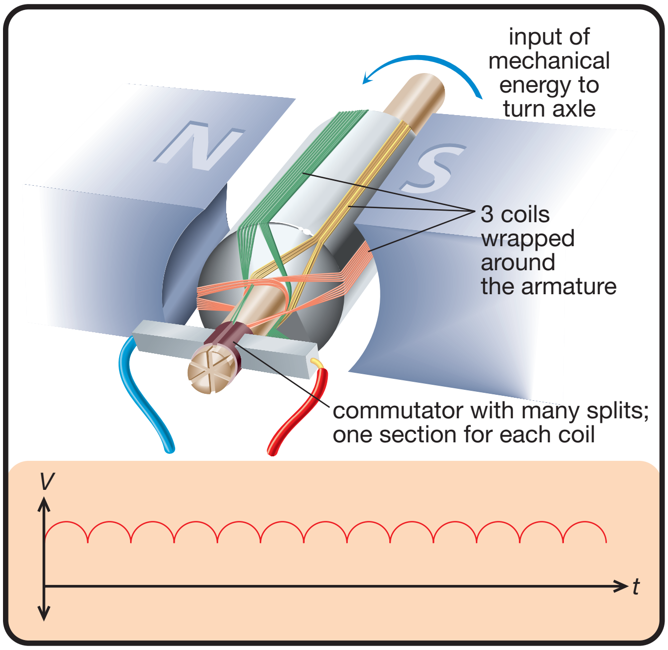


Figure C1.35

Despite the smooth output of well-designed DC generators, their use is not widespread. The most commonly used generators produce **alternating current**, or **AC**. Rather than try to remove any ripples from the output, an AC generator is designed to do exactly the opposite—to produce an electric current that makes one smooth sine wave, as shown in Figure C1.36.

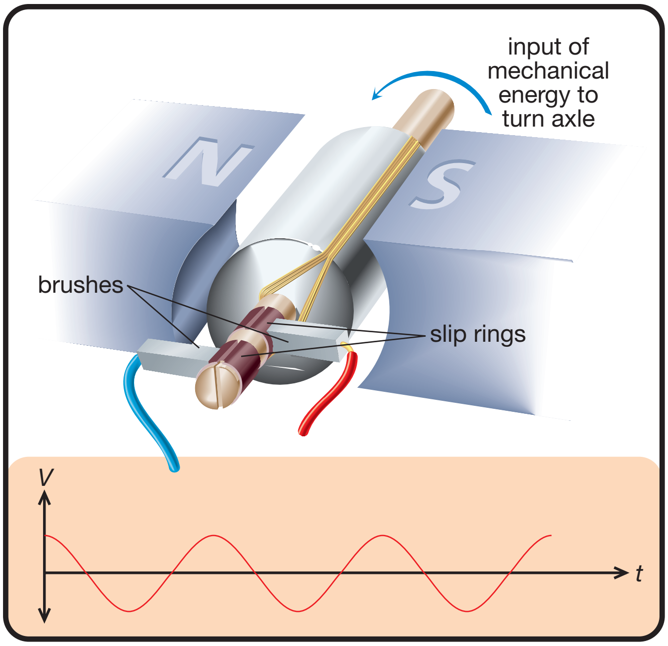


Figure C1.36

As you can appreciate from your work with building a motor, the speed of rotation of the armature can make it very challenging to learn more about a generator as it is operating. Computer animation is a great tool in these circumstances because you can adjust the rate of rotation and see the connections between the motion of the armature and the pattern of electric current produced.

Utilizing Technology

DC and AC Generators

Science Skills
✓ Performing and Recording
✓ Analyzing and Interpreting

Purpose

You will use computer animations to compare and contrast the design and function of a DC generator with that of an AC generator.

Procedure

Obtain the handout "Properties of DC and AC Generators" from the Science 30 Textbook CD. Follow the instructions in the handout as you interact with the applet "The Simple Generator," which can also be found on the Science 30 Textbook CD.

The Importance of AC Generators

As you read this book right now, are you using daylight from a window or an electric light source? If you're using an electric lamp of some kind, it's easy to take for granted that somewhere far from where you are sitting, the energy for that lamp is in some other form—coal, natural gas, or perhaps moving air. In each case, a generator is used to help convert one form of energy into the electrical energy that powers your lamp. Generators are the essential first step in making all your electrically powered modern conveniences possible. Without generators there could be no late-night TV, no microwave popcorn, and no cold drinks in the refrigerator. Later in this chapter you'll learn why the whole system for the transmission of electrical energy depends upon AC generators, which is why any device you plug into a wall is designed to run on alternating current.

Your previous work with the motor revealed key factors that maximize the motor's energy output. Since a generator involves the same basic components, these same factors also make for an efficient generator design. To maximize the energy output of a generator, you need to

- increase the number of turns of wire on the armature
- ensure that the armature is spinning as quickly as possible
- use strong magnets outside the armature
- place an iron core within the coils on the armature

Manufacturers of commercial generators incorporate all these features into their designs.

Using Headphones as Microphones

This lesson began with the unusual suggestion that a pair of headphones could be used as a makeshift microphone. Now that you know the basics about the connections between motors and generators, you should be ready to unravel this mystery.

Investigation

Connections Between Headphones and Motors

Science Skills

✓ Performing and Recording
✓ Analyzing and Interpreting
✓ Communication and Teamwork

Purpose

You will determine whether an efficient set of headphones can be used as a microphone. You will explore the process that makes this possible by disassembling a pair of inexpensive headphones.

Materials

- set of headphones that are efficient (capable of reproducing loud sound at low volume)
- inexpensive set of headphones to be disassembled
- access to a computer with speakers and a microphone input
- 4 AA cells in a plastic battery pack
- 2 test leads
- digital multimeter
- small slot screwdriver
- probe from a dissection kit
- portable music system (CD player, MP3 player, radio)
- "Disassembling Inexpensive Headphones" handout

Part A: Using Efficient Headphones as a Microphone

Procedure

step 1: Turn on the computer and test to see that the speakers are working by playing something that has a soundtrack.

step 2: Test that the efficient headphones work by connecting the headphones to the computer. Note that on most computers, the speakers connect through an output jack on the back that is identified with a label or a green colour-code. When you are sure the headphones are working, reconnnect the speakers and test them again to ensure you have reconnected them properly.

step 3: Locate the input jack for the microphone. This input is usually identified with a label or is colour-coded pink or red. Plug the headphones into this input.

step 4: Locate the "Sound Hardware Test" menu for the computer. On many computers, the process for finding this menu goes like this:
Start → Control Panel → Sounds, Speech, and Audio Devices → Adjust the System Volume → Voice → Sound Hardware Test

step 5: Follow the instructions on this menu to see if headphones really can function as a microphone. Remember, the headphones were not really designed to work this way, so you may have to speak loudly for this to work.

Part B: Disassembling Inexpensive Headphones

CAUTION!

- Inexpensive headphones can be purchased for only a few dollars, whereas the efficient headphones used in Part A may be significantly more expensive. Make sure you have not mixed up the two pairs before you begin disassembling the inexpensive pair.
- The inexpensive headphones still have to function as headphones after you have removed the outer bits of plastic. Work carefully and gently so as not to damage key internal parts.
- After the investigation, reassemble the inexpensive headphones if possible. Otherwise, place the headphone parts in a container marked “For Recycling of Electronics.”

Procedure

Obtain the handout “Disassembling Inexpensive Headphones” from the Science 30 Textbook CD. Follow the steps outlined on this handout to carefully disassemble an inexpensive set of headphones.

Analysis

1. Sketch the disassembled headphones and label the thin plastic diaphragm, the coil of fine wire, and the magnet assembly.
2. Determine whether headphones are designed to work more like a motor or more like a generator.

Part C: Testing the Disassembled Headphones

Procedure

step 1: Connect the headphones to a portable music system to ensure they still work.

step 2: Connect one end of the battery pack to the headphone plug with test leads, as shown in Figure C1.37.

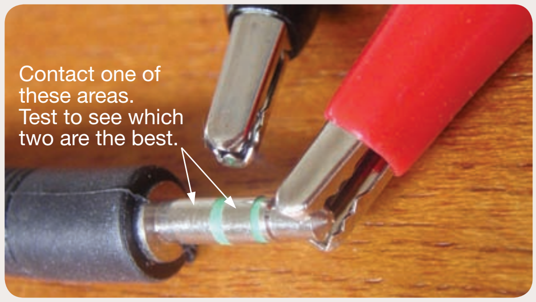


Figure C1.37

step 3: Make brief, intermittent contact with the other test lead connected to the battery pack. Observe the effect on the thin diaphragm.

step 4: Reverse the connections to the battery pack and repeat step 3.

Analysis

3. The diaphragm in each earpiece is supposed to vibrate back and forth. Sound waves are produced as these vibrations are transferred through the air. Combine this information with your previous observations to determine whether a pair of headphones is an AC or a DC device.

Part D: Using Disassembled Headphones as a Microphone

step 1: Set the digital multimeter to its most sensitive voltage setting so it is capable of measuring a few millivolts. Connect the disassembled headphones to the digital multimeter, as shown in Figure C1.38.

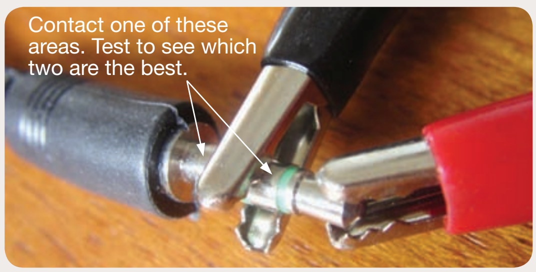


Figure C1.38

step 2: Very gently, using the tip of your finger, push the diaphragm up and down as you observe the output on the multimeter. Note your observations.

Analysis

4. As sound waves strike the thin diaphragm of a microphone, the diaphragm is forced to vibrate, moving the coil up and down relative to the magnet assembly. Combine this information with your previous observations to determine whether a microphone is designed to act more like a motor or more like a generator.

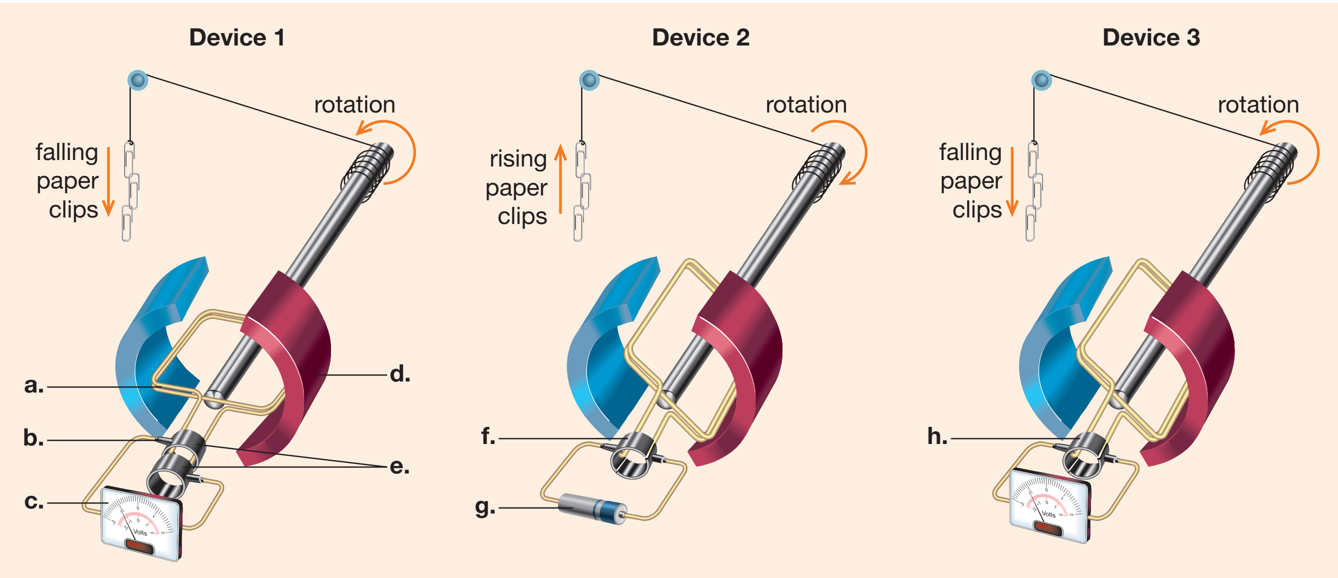
1.3 Summary

Motors and generators are devices that enable the conversion of mechanical energy into electrical energy. In the case of motors, the input is electrical energy and the output is mechanical energy. Generators reverse this process. In both cases, it is the motion of a conducting coil of wire through a magnetic field that makes this conversion possible. Most generators produce an alternating current (AC) instead of a direct current (DC). All of the electrical devices that plug into a wall outlet in your home are AC devices.

1.3 Questions

Knowledge

Use the following diagrams to answer questions 1 and 2.



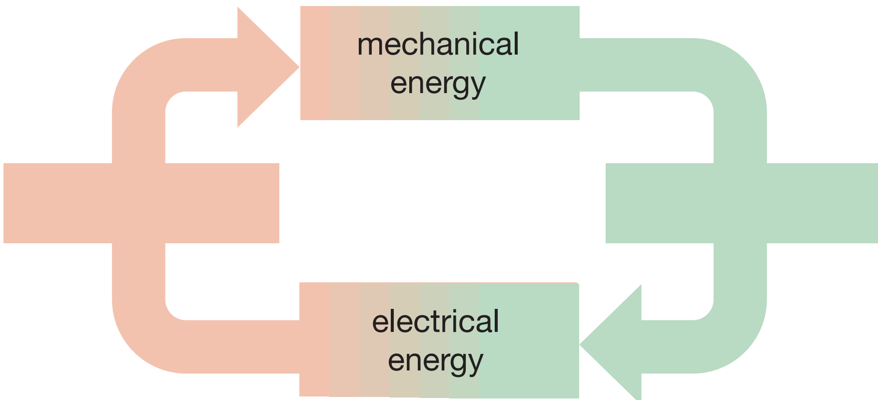
1. Determine which of these three devices is best described as a DC motor, a DC generator, and an AC generator.

2. Note that the key parts of each device are labelled with letters. Choose from the following list to identify each part.

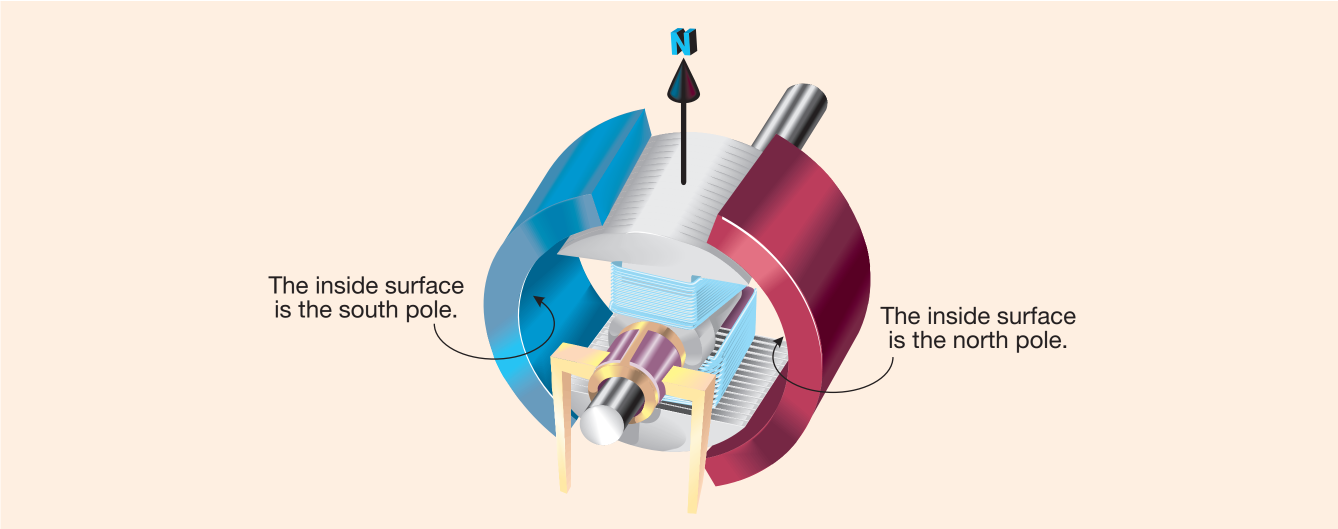
- rotating coil
- brush
- slip rings
- split-ring commutator
- voltmeter
- voltage source
- permanent magnet

Applying Concepts

3. Copy the following diagram into your notes. Add the words *headphones* and *microphone* in the appropriate places.



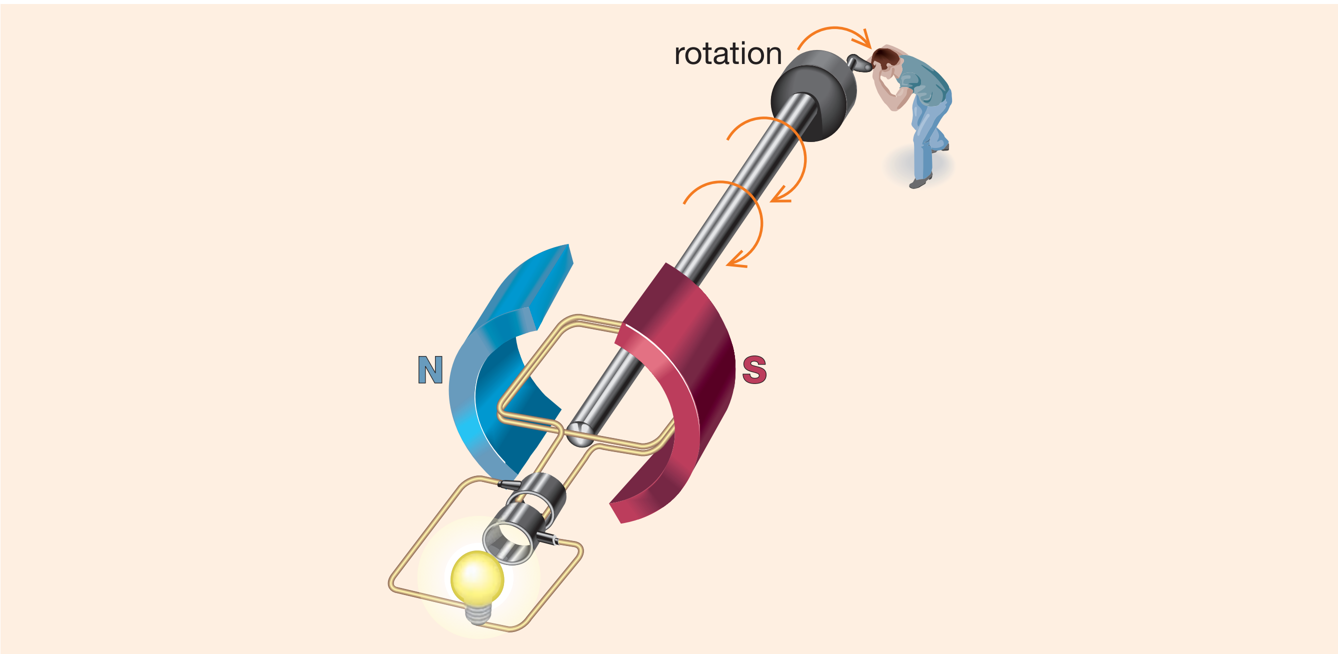
Use the following diagram to answer questions 4 and 5.



4. Determine which way this motor will turn.

5. Explain why this motor will continue to turn in the same direction.

Use the following diagram to answer question 6.



6. Sketch a graph of the voltage produced versus time for this device.

7. Show how the graph would change if the number of armature rotations per minute is increased.